Push Menu: Extending Marking Menus for Pressure-Enabled Input Devices

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ABSTRACT

Several approaches have been proposed to increase the breadth of standard Marking Menus over the 8 item limit, most of which have focused on the use of the standard 2D input space (x-y). We present Push Menu, an extension of Marking Menu that takes advantage of pressure input as a third input dimension to increase menu breadth. We present the results of a preliminary experiment that validates our design and shows that Push Menu users who are neither familiar with pen-based interfaces nor continuous pressure control can handle up to 20 items reliably. We also discuss the implications of these results for using Push Menu in user interfaces and for improving its design.

ACM Classification Keywords

H.5.2 Information Systems: Information Interfaces and Presentation – User Interfaces, Input Devices and Strategies.

Author Keywords

Marking Menu, Pressure Input, Pen-Based Interfaces.

INTRODUCTION AND RELATED WORK

Marking Menus [2] are radial menus where expert users can select items by drawing a straight gesture in the direction of the desired item, without popping-up the menu. While they perform faster than linear and Pie menus and facilitate the novice to expert transition [3], their accuracy even for expert users decreases when they have more than 8 items [2]. Even though they can be organized hierarchically to augment their capacity [3], their performance decrease and the 8-item limit at each level remains an issue for using Marking Menus in real applications.

Several improvements have been proposed to increase the capacity of Marking Menus while keeping their efficiency, accuracy and learnability. Zhao and Balakrishnan [10] improved the expert mode of hierarchical Marking Menus with a design where the user draws several marks instead of a single compound one. However, even if this design increases the potential depth of hierarchical menus, breadth remains a limiting factor for novice users and for menus with many items. Zone and Polygon Menus [9] address this issue with an alternate design that increases the breadth up to 16 items. However, Bailly *et al.* [1] pointed out that these improved designs have only been evaluated in expert mode, and raised the hypothesis that the transition from novice to expert may be impaired when compared with the original technique. They introduced the Flower Menu, a Marking Menu based on curved gestures that increases the breadth up to a theoretical limit of 56 items per level (20 in practice), and demonstrated its advantage for learning the expert mode.

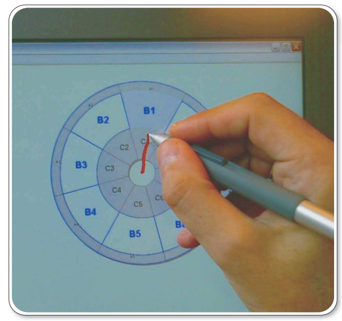

Figure 1. A Push Menu used on a screen tablet.

All these approaches share the same global principle of changing the menu layout and interactions to augment its capacity. The challenge is to find a trade-off between the gain in capacity and the complexity introduced by the new design, especially for keeping the smooth transition from novice to expert use. We propose instead to use another input channel / dimension to increase Marking Menu breadth while keeping its layout and interactions as close as possible to the original technique. Extra input channels have already been used in the Tilt Menu [8], where the angle of a stylus was used to activate and control a Marking Menu but did not increase its capacity. We focused our work on the use of *pressure* input rather than tilt for two main reasons: Pressure sentitive input devices are now widespread, and recent research, e.g. [5], has demonstrated the value of using pressure to augment interaction. Ramos has actually introduced a Pressure Marking Menu [6] similar to ours, but it has not been evaluated.

THE PUSH MENU

Push Menu (Figure 1) is a new Marking Menu design that makes use of continuous pressure input data to increase the number of items that a Marking Menu can contain. Each item is characterized by a direction, as with standard Marking Menus, and by a *pressure level*. It provides a dynamic feedback that enables novices users to browse across pressure levels, whereas expert users can directly select an item by drawing an oriented *pressure gesture* (Figure 2). In that

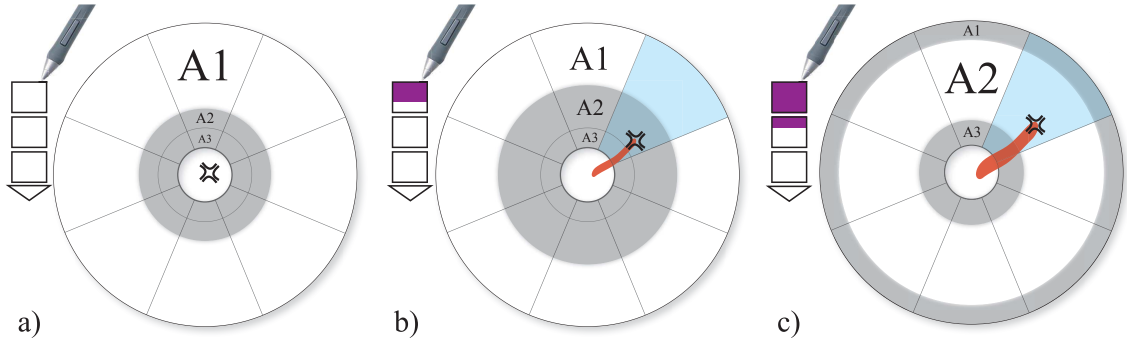

Figure 2. A 3-level Push Menu in different states: a) initial state (level 1 is active, colored in white). b) as the pressure increases, the ring of level 2 grows. c) when the applied pressure has raised above level 1, the level-2 ring is activated (in white) and the level-3 ring starts growing.

sense, the Push Menu is a *Pressure Widget*, inspired by the Bullseye design [5].

Push Menu is made of concentric rings. Each ring represents a level that is mapped to a pressure range. As with standard radial menus, rings are sliced up in sectors. Figure 2a depicts a Push Menu with 3 pressure levels and 8 directions in its initial state, just after it appears. The inner ring is activated with the highest level of pressure while the outer one is activated with the lowest level of pressure. The currently active level is enlarged and colored white. The other rings have a minimal width and are gray (Figure 2a).

As the pressure applied to the input device increases, the next inner ring grows from the center to the border (in Figure 2b, the ring representing level 2 is growing while the stylus is pressed). When the level of applied pressure exceeds the upper bound of the current level, the growing ring has reached its largest width and stops growing. The next level is then activated and the corresponding ring is colored white while the previously active ring is now gray (Figure 2c). The rings behavior is reversed when the applied pressure decreases.

The menu also provides feedback about direction by highlighting the sector under the cursor and by displaying a mark (Figure 2b&c). Selection can be cancelled by releasing the input device when inside the center area. To confirm a selection, the user releases the device when the cursor is over the desired item. We used this *Quick Release* method as it was demonstrated to outperform other methods [5]. It also makes the selection consistent with the ”expert mode” of the Push Menu that works like Marking Menus. The sole difference is that the width of the mark depends on the discretized level of pressure that is applied to the input device: for a 3-level menu, there are 3 different widths.

Pressure Discretization Function

Mapping the continuous pressure input data to the discrete levels of the Push Menu requires a transfer function. This issue has already been investigated in previous work and two solutions have been proposed. In [4], the pressure data is processed through several filters: a low-pass filter and a hysteresis to stabilize the signal, a parabolic-sigmoid transfer function that produces slow response at low and high levels and a linear behavior at intermediate levels. With this approach, the levels are not equally sized but static, i.e. they do not change during interaction. This approach was used successfully by Ramos *et al.* [5] and provides good control at intermediate pressure levels. In [7], a *fisheye transfer function* was proposed: The range of pressure levels changes according to the current level, as with a fisheye lense. This increases the accuracy of pressure control. For the Push Menu, we used a parabolic-sigmoid function as it improves the control of pressure without dynamically changing the range of levels. We hypothesize, but have not tested yet, that in expert mode, the fisheye transfer function may impair performance because of the lack of feedback.

EXPERIMENT

We conducted a controlled experiment to validate the Push Menu design and determine the number of pressure levels a user can reliably discriminate with or without feedback.

Apparatus and Participants

We used a Wacom Cintiq 21UX display tablet with its pressure-sensitive stylus. The experiment was run in full-screen mode, directly on the tablet display with an absolute one-to-one mapping (Figure 3). The experimental software was implemented in Java on a 2.16GHz Core Duo PC laptop running Windows XP Professional.

10 volunteers (8 male and 2 female), aged 25 to 35, participated in the study. All were right-handed and 6 had some experience with pen-based interfaces. 2 were familiar with pressure control while using pen-based devices, and 5 were familiar with mark-based interaction, but with a mouse.

Task and Stimuli

Participants were presented with several series of gestures to be drawn at 8 orientations and using up to 5 different levels of pressure (1 level representing the traditional Marking Menu). Our hypothesis was that participants would be performing well with up to 3 levels of pressure, but not more.

To investigate novice and expert performance, we considered two feedback conditions: *complete feedback (CF)*, which dynamically displays orientations and pressure rings as described above; *reduced feedback (RF)*, which only displays the stroke being drawn with the width proportional to the pressure level. In the *CF* condition, the menu is displayed immediately when the pen touches the screen (there is no delay) and the menu items are empty.

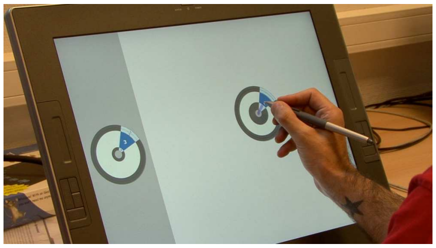

Figure 3. Experiment setup

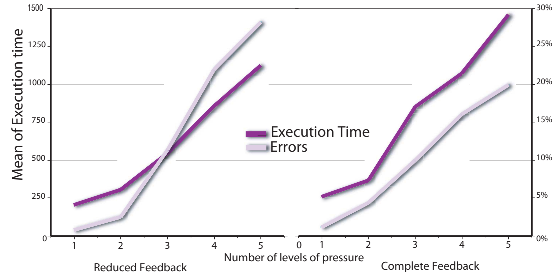

Figure 4. Execution time and errors across N and F

A graphical stimulus was presented to the participant at the beginning of each trial, which had the same appearance as the dynamic feedback used by the Push Menu (Figure 3). The rings were numbered to help participants quickly read the pressure levels. We use this stimulus because it is the same display that participants see in the complete feedback condition, while in the condition with reduced feedback it is expected to match the mental representation that participants have of the menu after performing with feedback.

After the stimulus was presented, participants had to draw the corresponding gesture in the right part of the screen, with feedback according to the trial condition. If the performed gesture was correct, participants were notified of their success with a green message. Otherwise, a red message notified the failure and the participant had to perform again until the expected gesture was drawn, with a limit of 10 attempts. We recorded two types of errors: *orientation errors*, when the gesture was not drawn in the right direction, and *pressure errors*, when the pressure level was not correct. We recorded *reaction time*, *execution time (ET)* (from the first time the participant touched the screen with the stylus until the right gesture was performed), *errors* (no error, orientation error, pressure error, complete failure after 10 attempts) and the *number of attempts*.

Design

A repeated measures within-subject factorial design was used. The independent variables were *Number of levels of pressure (N)* (*1, 2, 3, 4, 5*), *Amount of pressure (n)* (*1* to *N*), *Orientation (O)* (*N, NE, E, SE, S, SW, W, NW*) and *Feedback (F)* (*Complete (CF), Reduced (RF)*). Presentation of *Number of levels of pressure* was counter-balanced across participants. *Complete feedback* was presented before *Reduced feedback*. For each value of *Number of level of pressure*, the *Orientations* were paired with each *Amount of pressure*, repeated 3 times and randomly ordered within each block.

In summary, we had:
10 participants $\times$
5 Numbers of levels of pressure (1,2,3,4,5) $\times$
2 Feedbacks (CF, RF) $\times$
3 Blocks $\times$
8 Orientations (N, NW, W, SW, S, SE, E, NE) $\times$
1 to 5 Amount of pressure (according to the value of N)
= 7200 trials.

At the beginning of the experiment, the task was explained and demonstrated to the participants in each *Feedback* condition. Before each *Number of levels of pressure* and each *Feedback* condition, N$\times$8 practice trials were performed. Participants were instructed to draw the marks as quickly and accurately as possible. They could take small breaks every 12 trials and between changes of *Number of pressure levels*. Subjective evaluations were gathered with a short questionnaire at the end of the experiment.

RESULTS AND DISCUSSION

In the following analysis, we used Tukey HSD ($\alpha = 0.050$) for all post-hoc means pairwise comparisons. We first analyzed *Execution time* and *Errors* across the experiment blocks and found no significant learning effect. We observed a small improvement for Execution time and error rate for 4 and 5 levels of pressure, in both feedback conditions.

Number of Levels of Pressure and Feedback

Analysis of variance shows a significant main effect on *Execution time* for *N* ($F_{(4,36)}$ = 68.8238, p $<$ .0001) and for *F* ($F_{(1,9)}$ = 22.8201, p = 0.0010) and a significant $N \times F$ interaction ($F_{(4,36)}$ = 4.0729, p = 0.0080). An analysis of the means shows that the effect of *Complete feedback* is stronger on *ET* when *N* is greater than 3, but that *ET* is always lower with *RF* than with *CF*.

Analysis of variance also shows a significant main effect on *Errors* for *N* ($F_{(4,36)}$ = 100.0270, p $<$ .0001) and for *F* ($F_{(1,9)}$ = 7.3864, p = 0.0237) and a significant $N \times F$ interaction ($F_{(4,36)}$ = 8.0654, p $<$ 0.0001). An analysis of the means shows that the effect of *Reduced feedback* is stronger on *Errors* when the *N* is greater than 3, and that there are more *Errors* in the *RF* than in the *CF* condition.

Figure 4 illustrates these interaction effects and the behavior of the participants when controlling pressure. As expected, *Execution Time* increases with number of level of pressure. With 1, 2 and 3 levels of pressure, *ET* and *Errors* increase regularly in both feedback conditions with a behavior close to that of a standard Marking Menu: performance is better without feedback and accuracy is equivalent between 1 and 2 levels of pressure. It is worth noting that pairwise comparisons of means show no significant difference between 1 and 2 levels of pressure (216ms vs. 333ms execution time, 1% vs. 3.6% error rate), suggesting that the performance of a 2-level Push Menu is identical to that of a standard Marking Menu. With 4 and 5 levels of pressure on the other hand, participants spent more time adjusting the pressure level with complete feedback in order to be more accurate (more than 95% of errors are pressure level errors). Conversely, with-

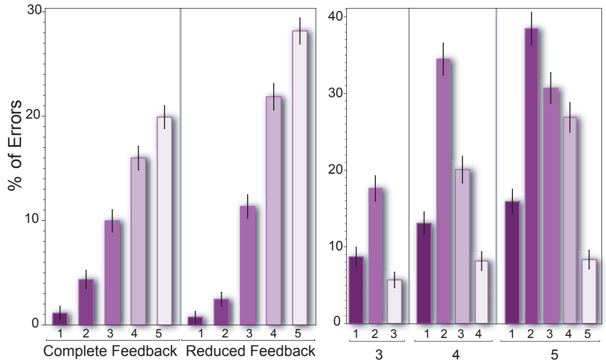

Figure 5. % of Errors: a) across N and F. b) across n for N = 3 to 5.

out feedback, they drew gestures more quickly, resulting in a higher error rate but a lower global task time.

Across the 2 feedback conditions, analysis of variance shows a significant main effect for *N* on *ET* (($F_{(4,36)}$ = 55.9083, p < .0001) for *CF* and ($F_{(4,36)}$ = 44.0075, p < .0001) for *RF*) and on *Errors* (($F_{(4,36)}$ = 33.2708, p < .0001) for *CF* and ($F_{(4,36)}$ = 96.8608, p < .0001)). In each cases, post-hoc analysis show that *Execution time* and *Errors* increases as the number of level of pressure increases. The error rates across *N* and *F* are illustrated in Figure 5a. The important point to notice is that 2 levels of pressure are acurate with Push Menu: 4.3% of errors with *CF* and 2.5% with *RF*; with 3 levels of pressure, error rates are largely higher: 9.97% of errors with *CF* and 11.4% with *RF*.

The error rates with 3, 4 and 5 levels of pressure are near twice those reported in [5] and they are obviously too high for practical use. However, the subjective evaluations showed that 70% of the participants were confident in their ability to control 3 levels of pressure after the experiment and 80% in their ability to control 4-5 levels of pressure after a daily use of the technique.

Target Level of Pressure and Orientation

Analysis of variance shows a significant main effect for the target level of pressure *n* on *ET* (for *N* = 2 to 5) and on *Errors* for *N* = 3 to 5: $F_{(2,18)}$ = 9.0458, p = 0.0019 for *N = 3*, $F_{(3,27)}$ = 23.4396, p < .0001 for *N = 4* and $F_{(4,36)}$ = 32.7134, p < .0001 for *N = 5*. In each case, post-hoc analysis shows that extreme pressure levels are faster to reach and are acquired more accurately than the intermediate levels (Figure 5b). This analysis shows the same results across the two *Feedback* conditions and confirms the subjective evaluation by the participants.

For *Orientation*, analysis of variance reveals a significant main effect on *Errors* only for the *RF* condition and for high levels of pressure. Further analysis is not really justified since there are very few orientation errors compared with pressure ones.

CONCLUSION AND FUTURE WORK

Push Menu is a variant of Marking Menu that uses pressure to increase the capacity beyond the traditional 8-item limit. It belongs to a wider class of Extended Marking Menus that is described in a companion paper submission.

Our evaluation suggests that a 2-level Push Menu (16 items) has the same level of performance as an 8-item Marking Menu, making it suitable for many applications [1]. Beyond 3 levels of pressure, performance is unacceptable for real applications. However an improved design could make 3-level Push Menu usable, *e.g.* by using level 2 for less frequent commands or by using a transfer function that improves the recognition of level-2 items.

Other future work includes investigating the hierarchical composition of Push Menu and their learning curve by conducting a long-term study.

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